Polarimetric Imaging Using Two Photoelastic Modulators

The frame rate is the difference between the resonance frequencies of the modulators.

A method of polarimetric imaging, now undergoing development, involves the use of two photoelastic modulators in series, driven at equal amplitude but at different frequencies. The net effect on a beam of light is to cause (1) the direction of its polarization to rotate at the average of two excitation frequencies and (2) the amplitude of its polarization to be modulated at the beat frequency (the difference between the two excitation frequencies). The resulting modulated optical light beam is made to pass through a polarizing filter and is detected at the beat frequency, which can be chosen to equal the frame rate of an electronic camera or the rate of sampling the outputs of photodetectors in an array.

The method was conceived to satisfy a need to perform highly accurate polarimetric imaging, without cross-talk between polarization channels, at frame rates of the order of tens of hertz. The use of electro-optical modulators is necessitated by a need to obtain accuracy greater than that attainable by use of static polarizing filters over separate fixed detectors. For imaging, photoelastic modulators are preferable to such other electro-optical modulators as Kerr cells and Pockels cells in that photoelastic modulators operate at lower voltages, have greater angular acceptances, and are easier to use. Prior to the conception of the present method, polarimetric imaging at frame rates of tens of hertz using photoelastic modulators was not possible because the resonance frequencies of photoelastic modulators usually lie in the range from about 20 to about 100 kHz.

It is conventional to characterize the polarimetric state of incident light in terms of the Stokes vector \((I, Q, U, V)\), where \(I\) represents the total intensity; \(Q\) represents the excess of intensity of light polarized at an angle designated as \(0^\circ\) over that of light polarized at a relative angle of \(90^\circ\), \(U\) represents similarly the excess of intensity at \(45^\circ\) over that at \(135^\circ\), and \(V\) represents the excess of intensity of right circular polarization over left circular polarization.

It has been shown theoretically that in the present method, there should be no cross-talk between the \(Q\) and \(U\) channels and that it should be possible to obtain the ratio \(U/I\) from two readings of a single photodetector taken when the polarizer is in two orientations that differ by \(45^\circ\).

The figure schematically depicts a laboratory setup that was used to demonstrate the feasibility of the method. A collimated beam of white light was partially polarized by a glass plate at an oblique angle. The degree of polarization could be changed by rotating the glass plate. The light then passed through a circular-polarization subsystem that included (1) two photoelastic modulators having their fast axes at an angle of \(0^\circ\), sandwiched between (2) two quarter-wave retarders oriented at angles of \(45^\circ\) and \(135^\circ\), respectively. The two photoelastic modulators had resonance frequencies of about 42 kHz, differing by a beat frequency of about 9 Hz. The modulated light was then made to pass through a \(0^\circ\) or \(45^\circ\) polarizer on the way to a photodetector. A band-pass filter having a nominal pass wavelength of 672 nm with 20-nm bandwidth was mounted between the polarizer and the photodetector. Results of several experiments at various degrees of linear polarization were found to agree substantially with theoretical predictions.

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